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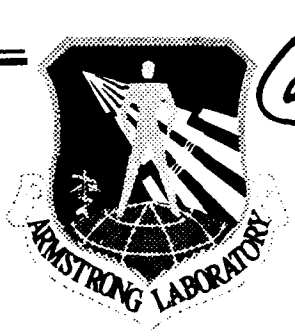

PHOTON ENERGY DEPENDENCE EVALUATION OF KEITHLEY INC'S 36000 SERIES ION CHAMBER RADIATION SURVEY METER

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OCCUPATIONAL AND ENVIRONMENTAL
HEALTH DIRECTORATE
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April 1991

Final Report

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AIR FORCE SYSTEMS COMMAND
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13. ABSTRACT *(Maximum 200 words)*

At the request of the USAF Radioisotope Committee, the Air Force Occupational and Environmental Health Laboratory, Radiation Services Division, conducted a photon energy dependence evaluation of Keithley Inc's 36000 series ion chamber radiation survey meter. This information was used to determine the applicability of the manufacturer's calibration procedure, which uses low energy x-rays, to the measurement of high energy photon emitting sources.

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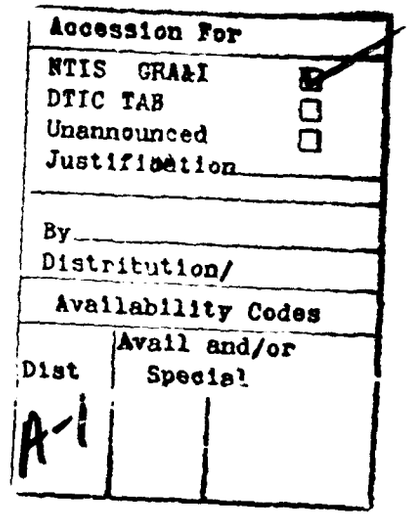

Illustrations

I. INTRODUCTION

The radiation protection instrumentation used in large medical centers throughout the Air Force is often called upon to handle a wide spectrum of radiation emitting sources and devices with photon energies ranging from low energy x-rays (~30 kiloelectron Volts (keV)) to high energy Co-60 (1252 keV average) teletherapy sources and possibly even higher energy photons from linear accelerators. It is not possible to calibrate a survey instrument for every energy it may encounter. It is possible; however, to evaluate the response characteristic of an instrument over a wide-range of energies and from this choose a suitable point for subsequent calibration of the instrument thereby providing acceptable accuracy over this range.

This study was conducted at the request of the USAF Radioisotope Committee (RIC) because of concern about the adequacy and applicability of Keithley Instrument Inc's calibration procedure for its 36000 series instruments. Because these instruments were being used in the Air Force Medical Center environment to fulfill the requirements under the master material licence granted to the Air Force by the U.S. Nuclear Regulatory Commission (NRC), the RIC requested an opinion from the NRC on the matter. The NRC's policy is that it is the user's responsibility to determine the adequacy of the calibration procedures for the specific instrument and the environment in which it is used. The NRC's opinion is included in the Appendix. Subsequently, the RIC asked us to evaluate the adequacy of the manufacturer's calibration procedure for this series of instruments.

II. DISCUSSION

The Keithley 36000 series survey meters are based on an air equivalent 250 cm^3 vented ion chamber. The chamber window consists of a 50 milligram per square centimeter (mg/cm^2) polycarbonate material. The unit is also provided with a removable 367 mg/cm^2 build up cap which is used for photons above 300 keV to ensure electronic equilibrium conditions in the chamber are maintained. The unit's exposure rate ranges, 20 Roentgens per hour (R/hr), 2 R/hr, and 200 milliRoentgens per hour (mR/hr) are user selectable via a knob on the back of the unit and have resolutions of 10 mR/hr, 1 mR/hr, and 0.1 mR/hr, respectively. Readout is provided by a 4-digit LCD display on the rear of the unit. The manufacturer's published energy response is ±10% from 12 keV to 300 keV without the build up cap and ±10% from 32 keV to 2 MeV with the build up cap.

The manufacturer's calibration of the instrument consists of exposure to machine produced bremsstrahlung x-rays using the National Institute of Standards and Technology (NIST) L100 technique (100 kiloVolts peak (kVp), 2.70 mm Al half-value-layer (HVL)) to generate the spectra. Calibration of the x-ray machine is performed using an NIST traceable ion chamber and a calibrated electrometer. Calibration accuracy of the instrument is published by the manufacturer as ±5% of the value obtained with the NIST traceable chamber and readings are standardized to 22°C and 760 mm Hg. The x-rays emitted using this technique consist of a continuum of energies from a few keV

Note: This report was accomplished by the Air Force Occupational and Environmental Health Laboratory (AFOEHL) which is now the Armstrong Laboratory, Occupational and Environmental Health Directorate.

to a maximum of 100 keV. The effect of the filtration added to meet the HVL criteria is termed beam "hardening." This is the preferential attentuation of the lower energy photons as they pass through the filter material and results in a spectrum with a greater percentage of photons at higher energies (Fig 1). For this particular technique; however, the resulting x-ray spectrum is not monoenergetic enough to derive a single effective energy capable of adequately describing the characteristics of the beam when it undergoes interaction. For this reason there are no published effective energy values for this technique.

In addition to x-ray irradiation compatible to the manufacturer's, two other photon emitting sources were selected to provide widely spaced points in the manufacturer's advertised energy range for the instrument. Cs-137 (662 keV) and Co-60 (1252 keV[1]) met the criteria and were conveniently available. The data collected using these three sources were applied to the calculation of energy dependence. The calculation was performed according to American National Standards Institutes (ANSI) Standard N42.17A, "Performance Specifications for Health Physics Instrumentation - Portable Instrumentation for Use in Normal Environmental Conditions." Section 6.3 (Photon Energy Dependence) of this standard defines the energy range of an instrument as: "The useful energy range for photon measuring instruments shall be stated, and graphically indicated, and shall be the continuous interval of photon energies over which the following condition is met:

$$0.8 \leq \frac{(\bar{r}_{en_i}/CTV_{en_i})}{(\bar{r}_{ref}/CTV_{ref})} \leq 1.2$$

in which

$\bar{r}_{en_i}$ = the mean indicated reading to photon radiation of energy (i)

$\bar{r}_{ref}$ = the mean indicated reading to the reference photon radiation

CTV_{en_i} = the conventionally true value of the photon radiation of energy (i)

CTV_{ref} = the conventionally true value of the reference photon radiation (L100 x-rays)."

For the purpose of this study, the reference photon irradiation is taken as L100 x-rays and the conventionally true values taken as those determined using the reference ion chamber and electrometer for each source.

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1. Co-60 emits two photons, 1173 keV and 1332 keV, upon decay. The average of the two, 1252 keV, was used for the purposes of this report.

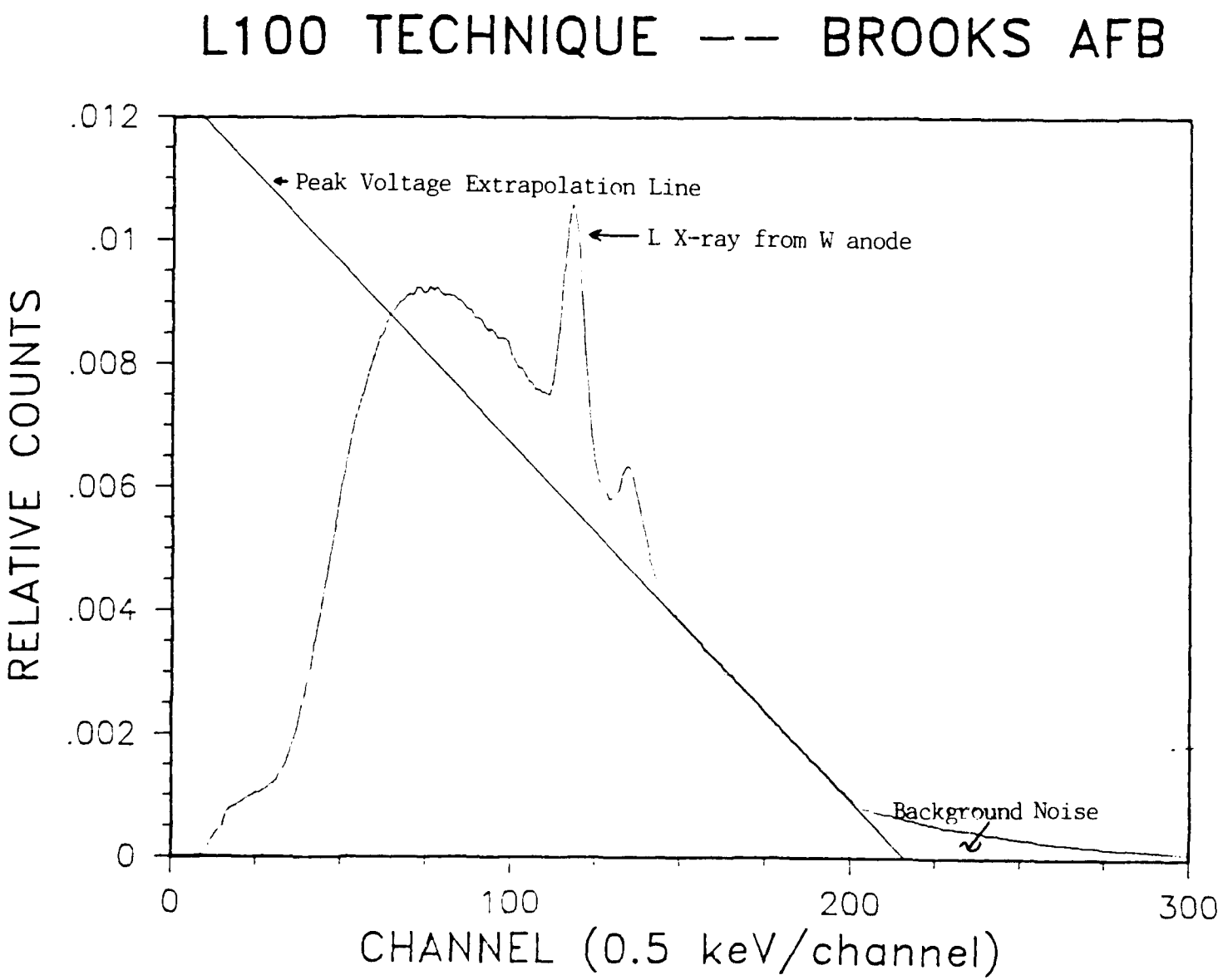

Figure 1. L100 Energy Spectrum

III. PROCEDURE

A. In order to establish the energy dependence curve for the instrument in relation to the manufacturer's calibration point, three sources were selected:

1. L100 x-rays produced by a Seifert Inc, 420 kVp x-ray calibration system installed at building 1193, Brooks AFB. The exposure rate was determined using an Exradian Inc Model A-4 ion chamber, serial number 146, calibrated 21 Jul 89 by NIST and a Keithley Inc Model 35617 electrometer, serial number 26467, calibrated 9 Nov 89.

2. 662 keV gamma rays produced by a J.L. Shepard, Cs-137 (130 Ci), Model 81-10 Beam Calibrator, installed at building 1193, Brooks AFB. The exposure rate was determined using an Exradian Model A-2 ion chamber (with build-up cap installed), serial number 161, calibrated 19 April 1989 by NIST and a Keithley model 35617 electrometer, serial number 27674, calibrated 9 Nov 90.

3. 1173 keV and 1332 keV gamma rays produced by an Atomic Energy Corporation, Co-60 teletherapy source installed at building 186, Brooks AFB. The exposure rate was determined using an Exradian Model A-3 ion chamber, serial number 111, calibrated 15 Jan 89 by NIST and a Keithley Inc model 617 electrometer, (calibration data unavailable[2]).

B. The exposure rate from each source was first determined using a NIST traceable ion chamber and a calibrated electrometer. The ion chamber was then replaced with the instrument to be evaluated. A closed circuit television system was used to remotely read the display of the instrument during the irradiation. Readings were taken 5 seconds after the exposure was initiated (this corresponds to the R-C time constant of the detector circuit). Readings were monitored for approximately one minute to evaluate stability. All exposure rate ranges were evaluated with Cs-137 and Co-60 only. The lowest exposure rate of the x-ray calibration system is approximately 1 R/hr which precluded evaluation of the lowest range of the instrument under test.

IV. RESULTS

The results (the Table) show an energy dependence over the energy test range which falls within the bounds of the ANSI N42.17A standard. The standard deviation between the four test instruments shows acceptable reproducibility. A plot of the data is shown in Figure 2. For this plot, the average energy dependence across all exposure rates was calculated for each energy. This average was then used as a data point for the plot.

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2. Calibration certificate was unavailable at the time of testing. Subsequent calibration of instrument demonstrated that it was still within required accuracy specifications.

V. CONCLUSIONS

This instrument meets the criteria set forth in ANSI N42.17A for use with the range of photon energies encountered in the medical center environment when calibrated with L100 x-rays. Although the instrument does show a slight energy dependence over the range of interest, a calibration involving multiple energies would be of low or no benefit considering the cost of such a calibration and the intended use of the instrument.

Energy Dependence Data Keithley 36000 Series Ion Chamber

		Instrument Number						
	True Exposure Rate (R/hr)	1	2	3	4	Mean	Standard Deviation	Energy Dependence
L100	11.20	10.04	10.35	10.4	10.64	10.36	0.25	1
	1.16	1.03	1.04	1.04	1.04	1.04	0.01	1
Cs-137	9.28	9.02	9.3	9.3	9.21	9.21	0.13	1.07
	0.928	0.89	0.94	0.9	0.92	0.91	0.02	1.13
	0.116	0.11	0.11	0.11	0.11	0.11	0	1.06
Co-60	4.46	5.03	4.46	4.91	4.83	4.81	0.25	1.17
	1.65	1.8	1.77	1.73	1.73	1.76	0.03	1.19
	0.160	0.17	0.17	0.17	0.17	0.17	0	1.2

Table: Results

Energy Dependence of Keithley 36000 Series Ion Chamber

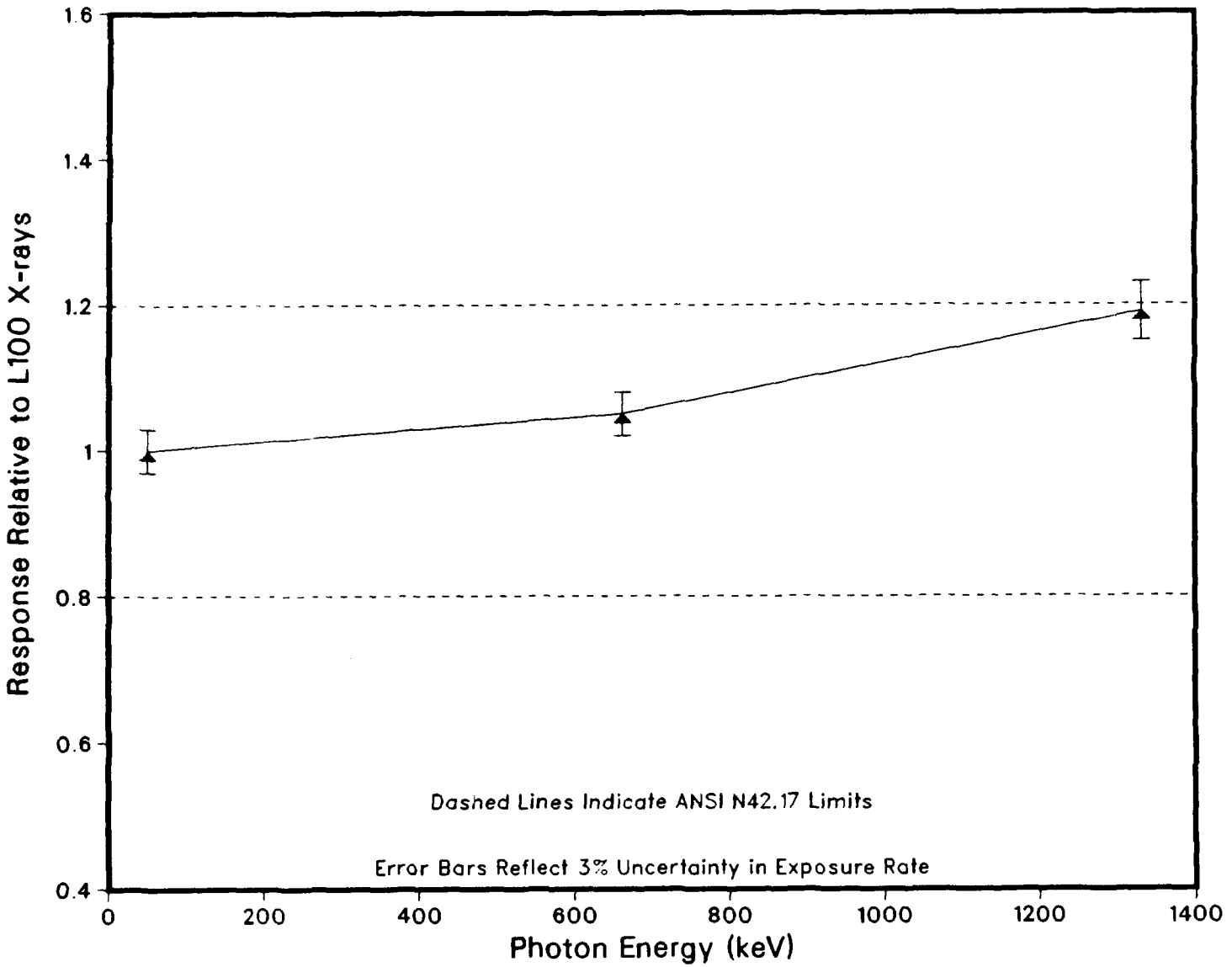

Figure 2: Energy Dependence

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APPENDIX: NRC Opinion

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION IV
611 RYAN PLAZA DRIVE, SUITE 1000
ARLINGTON, TEXAS 76011

15-A-5

MAR 19 1990

In Reply Refer To:
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Docket: 030-28641

Department of the Air Force
ATTN: Col David G. Wood
USAF Radioisotope Committee
HQ AFOMS/SGPR
Brooks AFB, Texas 78235-5000

Gentlemen:

SUBJECT: CALIBRATION OF SURVEY INSTRUMENTS

On April 6, 1989, Major Donovan wrote to NRC Region IV regarding Keithley Instruments' use of X-ray sources to calibrate survey instruments as required by 10 CFR 35.51(a)(1). On November 15, 1989, he mentioned to Bill Fisher his belief that Keithley was going to send their survey instrument calibration procedures to NMSS for review. On March 6, 1990, Janet Schlueter of NMSS informed Bill Fisher that Keithley had forwarded their calibration procedures at the request of Major Donovan.

After some discussion within NMSS and Region IV, we have concluded that it would be inappropriate for NRC to endorse specific calibration procedures for Keithley or any other commercial calibration service. It is the responsibility of the licensee to ensure that survey instruments are calibrated in compliance with 10 CFR 35.51. This section does not define "calibration" in terms of energy dependence or certain other measures of calibration quality. The licensee is expected to review the calibration procedures employed for all instruments used by the facility for the detection and measurement of radiation and to explain such procedures upon request during NRC inspections. The regulations do not specify the type of radiation source to be used to ensure that instruments are capable of measuring the intended radiation. However, given the energy dependence of some instruments, there is an obvious advantage to calibrating with radiation types and energies similar to those to be measured or detected.

This position should not be compared with the one we took recently regarding the use of pulsers in the OEHL calibration procedures. In that case, the instruments were to be calibrated with radiation sources and the calibrations extrapolated using electronic pulsers. Our letter of November 9, 1989, indicated no objection to the use of pulsers as described in the OEHL procedures. It presumed that the calibration sources used in the procedures would be appropriate for the detectors being calibrated and the radiation to be measured.

If you wish to discuss this matter further, please contact Bill Fisher at (817) 860-8215.

Sincerely,

A. Bill Beach, Director
Division of Radiation Safety
and Safeguards

cc:
Lt Col James H. Dunlap
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